

EXHIBIT A
STATEMENT OF WORK
FOR

Low Noise and Large Area APD Development for CO₂ LIDAR

1.0 Introduction/Background

Global CO₂ observation from satellites is very important to our understanding of global carbon cycle and climate change. More accurate measurements at a higher spatial resolution, by space-based LIDAR, will provide the needed data to identify sources and sinks of CO₂ and improve climate models. Current leading concepts for space-based CO₂ LIDAR include 2 μ m systems and 1.5 μ m. Studies indicate that 2 μ m systems are preferred due to its higher sensitivity to the boundary layer and lower troposphere where CO₂ sources and sinks are located and where CO₂ concentration has the greatest variability. One of the key enabling technologies for the 2 μ m CO₂ LIDAR is large diameter and ultra low noise detectors.

Raytheon has developed breakthrough HgCdTe APD Detector technologies for LIDAR/LADAR applications with substantial funding from the Department of Defense (DOD) and Raytheon Internal Research and Development (IR&D) program. These HgCdTe detectors have achieved very high quantum efficiency and ultra low noise from 1.0 μ m to 2.5 μ m. In the first phase of this development, 200 μ m diameter HgCdTe APD devices have been designed, fabricated, integrated into a compact liquid nitrogen dewar. In conjunction with a very low noise amplifier, detector noise of E-14 W/rt(Hz) has been demonstrated. This has been a very successful collaborative effort. Open and timely information exchanges between Raytheon and NASA LaRC and participation in the testing and characterization of the detector by NASA scientists and managers have been critical to the success of this developmental program. The focus of the second phase of this program is to optimize the performance of the APD detector by further reducing the amplifier noise and advance TRL level by demonstrating detector operation in long life-time TEC or mechanical cryogenic coolers. This demonstration is an essential next step in maturing this technology for space-based CO₂ lidar applications.

2.0 Objectives and Scope of Work

The objectives proposed scopes of work for the second phase of this low noise and large area APD development for CO₂ LIDAR include:

- 1) Providing support to NASA LaRC team in the testing and integration of the prototype APD detector in a liquid nitrogen dewar into the existing NASA LaRC CO₂ LIDAR test bed. NASA LaRC team plans to integrate this prototype APD detector into the CO₂ LIDAR test bed and collect data to demonstrate its feasibility and sensitivity.
- 2) Performing amplifier re-design with a lower bandwidth (2 MHz or 5 MHz TBD by NASA) to further reduce overall APD detector subsystem noise by a factor of 2 (Goal). Testing of the current prototype APD detector indicates that the noise performance is amplifier noise limited.
- 3) Conducting TEC or long-life mechanical cooler packaging design and trade studies. Depending on the final optimum operating temperature of the APD device, we can either use a TEC cooler, if the APD optimum operating temperature is 200K or above, or a very compact closed cycle cooler, the standard advanced dewar assembly II (SADA II), used

in Raytheon military products. The TEC cooler being considered is the Raytheon thermal weapon sight (TWS) cooler. It is at > TRL 7. Figure 1 shows the TWS dimensions. It is very compact at [REDACTED] inches. Figure 2(a) and Figure 2(b) are CAD layouts illustrating the packaging of the APD detector in the TWS III cooler. Raytheon is manufacturing thousands of SADA II for U.S. Army. It is also at >TRL 7 with demonstrated life time of > 10 years. Figure 3 is a picture of SADA II for U.S. Army. Figure 4 shows the dimensions of the SADA II closed cycle cooler. The height is [REDACTED] inches. A conceptual design on packaging the APD detector into the SADA II closed cycle cooler is illustrated in Figure 5. We want to point out that SADA II closed cycle dewar is more expensive than the TWS TEC cooler. Our proposed cost is based on the TWS TEC cooler.

- 4) Install one TSA with two working APDs in one TWS or one SADA II dewar. Cooler selection will be based on design and trade studies described in 3).

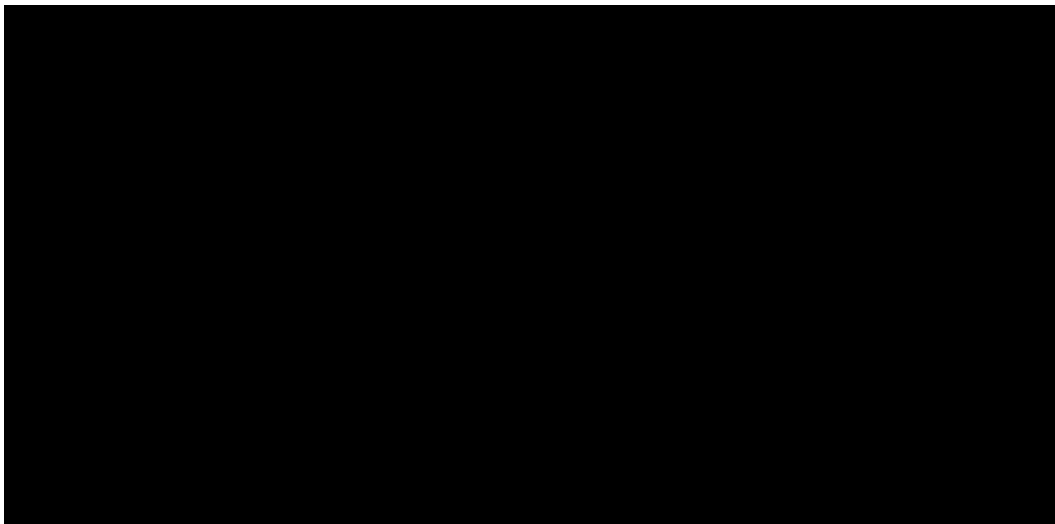


Figure 1. TWS TEC cooler dimensions [REDACTED]

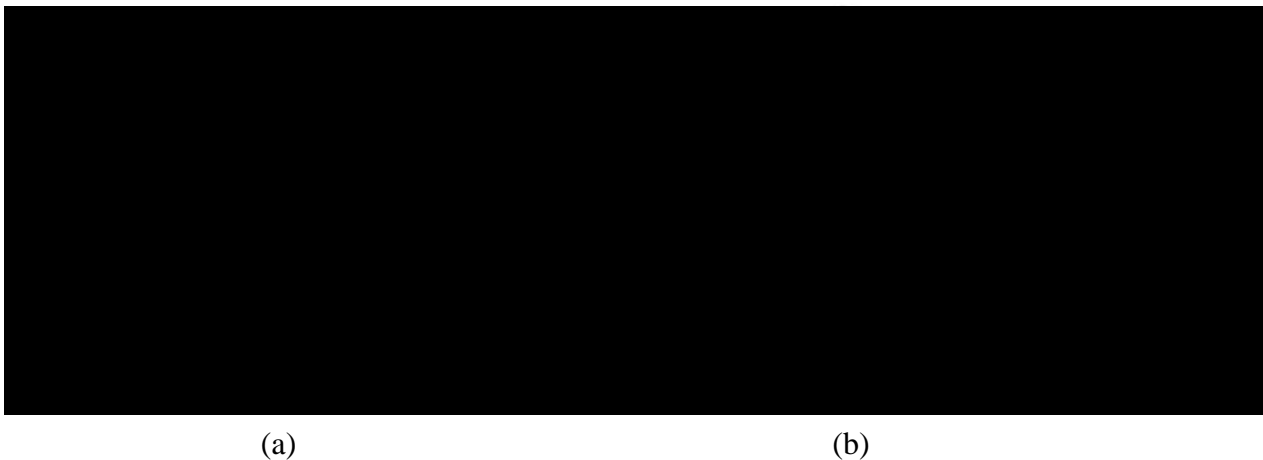


Figure 2. Low noise 2 μ m APD detector in TWS cooler: (a) with cold shield; (b) without cold shield.



Figure 3. Raytheon standard advanced dewar assembly II (SADA II).

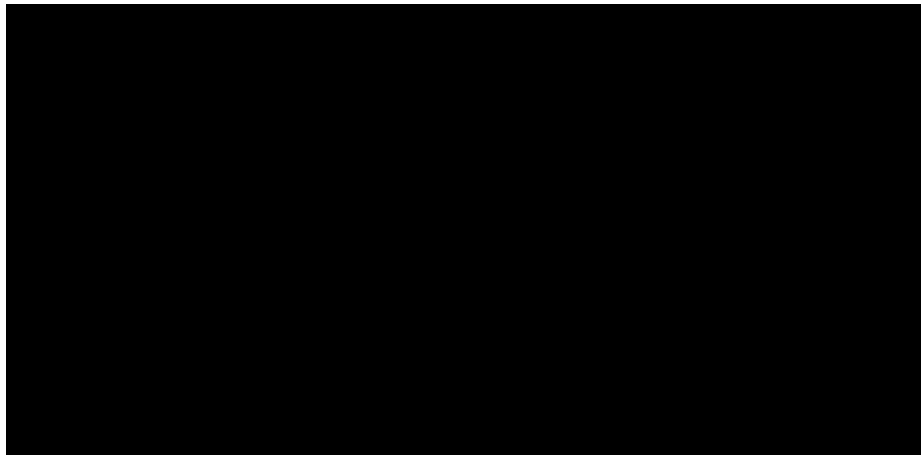


Figure 4. SADA II cross section views and dimensions.

